

Issued March 7, 1913

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN 524.

TILE DRAINAGE ON THE FARM.

BY

A. G. SMITH,

*Agriculturist, Office of Farm Management,
Bureau of Plant Industry.*



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., October 29, 1912.

SIR: I have the honor to transmit herewith a manuscript entitled "Tile Drainage on the Farm," by Mr. A. G. Smith, Agriculturist, Office of Farm Management, of this Bureau, and to recommend its publication as a Farmers' Bulletin, superseding No. 187, entitled "Drainage of Farm Lands," which has been discontinued.

The manuscript was prepared to meet the demand that is arising all over the country for information on this subject. It is not designed to apply to large drainage projects involving engineering problems, but to cover the subject fully from the farmer's point of view.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Need of drainage.....	5
Ideal system of drainage.....	5
Importance of the outlet.....	6
Kinds of tile in use.....	8
Clay tile.....	8
Cement tile.....	9
Proper size of tile.....	10
Locating the tile drain.....	11
Depth of tile and distance between laterals.....	13
Preparing to lay the tile.....	14
Getting the necessary fall.....	14
Drainage tools.....	15
Digging the ditch.....	16
Digging to the grade.....	17
Laying the tile.....	19
Filling the ditch.....	20
How water enters the tile.....	21
Life of a tile drain.....	21
Use of silt basins or sand traps.....	22
Protection of the mouth of a drain.....	22
Lands that require artificial drainage.....	22
Draining hillsides.....	23
Draining ponds.....	23
Cost of tile drainage.....	24
Benefits of drainage.....	25
Profits from draining.....	26

ILLUSTRATIONS.

	Page.
FIG. 1. Outlet ditch, showing how the dirt should be thrown back from a ditch so that it can be leveled and plowed.....	6
2. Large outlet ditch with the ground leveled on both sides.....	7
3. Sketch showing a "random" drainage system and the location of tile used in draining 40 acres of land in Scott County, Ill.....	12
4. Sketch showing a system of drainage in which the cost of installing is increased by too much double draining.....	13
5. Sketch showing a system of drainage by which the area of double-drained land is reduced to a minimum.....	13
6. Drainage tools.....	15
7. Sketch showing the straight course that a tile drain should take instead of following the sharp turns of an old watercourse.....	16
8. Laborers digging a ditch preparatory to laying tile at Columbia, S. C..	17
9. Laborer digging to the grade by means of crossbars and a tight line.....	18
10. Laborer laying tile.....	19
11. A 4 by 6 inch Y tile.....	19
12. Laborer priming tile.....	20
13. Laborers filling a ditch with a turnplow to which a long evener is attached.....	21
14. Mouth of a tile drain.....	22
15. Sketch showing a line of tile laid around the edge of a pond to intercept seepage water and across the pond to drain it.....	24

TILE DRAINAGE ON THE FARM.

NEED OF DRAINAGE.

The United States needs more drainage. Good examples of drainage can be found in practically every State, but there are millions of acres that still require it. The Middle Western States have done the most draining, Ohio, Indiana, Illinois, and Iowa leading in this respect. Of the clay draitile manufactured in the United States in 1910, the product of these four States was 85.5 per cent of the entire output.

Although there is urgent necessity for drainage in Minnesota, Michigan, Wisconsin, Missouri, Arkansas, and New York, comparatively little has been done. Along the coast from New Jersey to Texas, inclusive, every State has gigantic drainage problems almost untouched, while throughout the country there are lands that must be drained before maximum returns can be obtained. In reality, drainage in the United States is only fairly begun, and its immense possibilities are but little known.

IDEAL SYSTEM OF DRAINAGE.

An ideal system of drainage is adequate, permanent, not a hindrance to cultivation, and uses the least possible land. Such a system is most nearly secured by the use of large outlets, either open or covered, into which tile drains empty.

The open-ditch system commonly found in the South Atlantic and Southern States, and occasionally in other parts of the country, does not fulfill these requirements. Valuable land is occupied by this system, and the drainage is seldom thorough. Unless well cared for, the ditches become filled, and it costs heavily in time and money to keep these cleaned out and to keep the brush and weeds cut off the bank. The fields are cut into small tracts, thus making short rows, hindering the use of improved machinery, and increasing the expense of cultivation. Sometimes the area occupied by the open ditches themselves is as much as 10 per cent and frequently 5 per cent of the area drained.

IMPORTANCE OF THE OUTLET.

In draining land, the outlet is the first consideration. On rolling or hilly lands this is ordinarily present, as the water washes out a channel, although for best service it may need straightening or cleaning out. On low, level land an artificial outlet is usually necessary. Where all the land needing an outlet is owned by one man, he must provide it at his own expense. Where two or more farms or a district require a common outlet, the costs should be paid by assessments on all the land benefited. The topography determines the boundaries of a district. It may contain only a few thousand acres or it may be several hundred square miles.

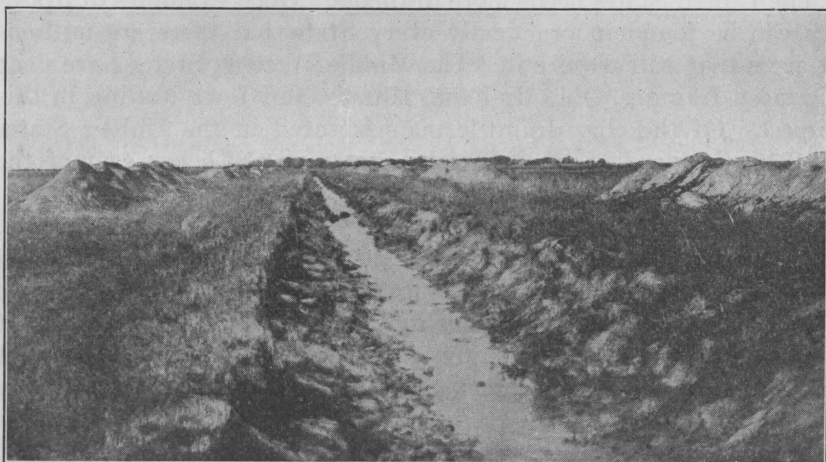


Fig. 1.—Outlet ditch, showing how the dirt should be thrown back from a ditch so that it can be leveled and plowed.

In making a drainage outlet for an individual farm the services of an engineer may or may not be required, depending on the ability of the owner of the land or the man who has charge of the work. In providing district outlets, however, an engineer is necessary.

An outlet for level land should be straight and deep. Curves and crooks check the flow of water and are likely to cause the ditch to fill. Other things being equal, water flows more rapidly in a deep ditch than in a shallow one. Vegetation is not so likely to grow in the bottom of the deep ditch. It may be necessary to place branch drains deep at the beginning to secure sufficient fall, so the outlet should be deep enough to take care of this. Except under extraordinary conditions, where it is impossible, a district outlet for level land should never be less than 6 feet deep. Within reasonable limits the deeper the outlet ditch the more efficient it will be.

All the fall possible consistent with good management should be secured for open ditches. These work well with a drop of 4 feet to

the mile, but of necessity some are made with as little as a 1-foot drop.

The sides of a ditch in loamy soils subject to freezing should be made at an angle of 45° . In sandy soils more slope is necessary, while in stiff soils subjected to little freezing less will do. If the sides are made vertical or nearly so, the earth affected by the water will cave in and partially fill the ditch.

These outlet ditches are usually excavated with a dredge, although, if the soil is not too wet, teams and scrapers may be used.

Outlets should follow in general the natural course of the water. If they can be located by the side of roads they will not divide fields

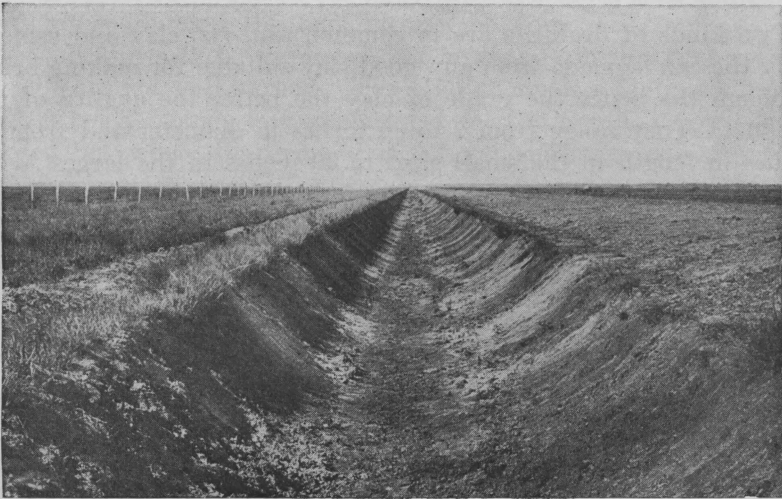


FIG. 2.—Large outlet ditch with the ground leveled on both sides. The dimensions are 6 feet deep, 6 feet wide at the bottom, and 22 feet wide at the top.

nor will they be seriously in the way of farming operations. The ditch will drain the road and the earth excavated may be used in building it. Sometimes to promote efficiency and economy in the drain it may be necessary to divert the outlet from the natural watercourse.

Where the ditch runs through a field the earth should be thrown several feet back from the bank instead of close to it (fig. 1), so the farmer can level it and plow over it. Openings should be made in the earth at intervals to let the water through. Figure 2 shows a large outlet ditch with the ground leveled on both sides.

In the Middle West, where the price of land is high and the art of drainage is well advanced, tile as large as 3 feet in diameter are frequently used to take the place of open ditches as farm and district outlets. The tile have the advantage of being closed over and thus do not occupy tillable land or divide a field. Where properly laid

there is no danger of the tile filling and there is but little if any maintenance expense. Water will run faster through a tile than in an open ditch; hence, the tile can be much smaller than the open ditch. The open ditch has an advantage in holding more water after a rain, though perhaps not carrying more. Because they are in a position to know the value of the improvement made by closing an open ditch, farmers must determine for themselves when it is profitable to use tile.

Most States have drainage laws which cover the legal points involved in making the district outlets.

KINDS OF TILE IN USE.

Two kinds of draintile are in common use, viz, clay and cement. Clay tile can be made from any good clay suitable for making brick, although the better the grade of clay the better the quality of the product. They range from 2 to 36 inches in diameter and from 12 inches in length in the small sizes to 30 inches in the largest. All tile should be free from warps, uniform in shape, and smooth at the end. In Ohio and the States to the east both the hexagonal and the round tile are manufactured, but west of this only the round tile are made. Some eastern farmers prefer the hexagonal and octagonal to the round forms, claiming that they are more easily laid. Others prefer the round tile, giving the same reasons for their preference. The hexagonal and octagonal tile are not as strong as the round and will not hold up as much weight. The round are more easily shipped and hauled. Both kinds do effective work, but the proportion of hexagonal and octagonal used in comparison with round is small, probably being not more than 2 per cent of the total. The writer prefers the round tile.

CLAY TILE.

Soft, medium, and hard-burned or vitrified clay tile are made. It costs less to make the soft-burned than the hard-burned tile and the selling price is lower, but the quality is not so good. Soft-burned tile have done good service, however, and when put under ground below the frost line have lasted indefinitely. The best tile are burned to a cherry red and when struck by a piece of steel give a sharp, metallic ring. In the North, where they are laid above the frost line, only the hard-burned tile should be used. Hard-burned, or vitrified, tile are practically nonporous; thus, they absorb little moisture and unless water stands in them they are not injured by freezes. A tile that cracks and shatters in winter when lying in the yards unprotected from the weather is not fit to use above the frost line and is not the best under any conditions.

Thick tile make the best joints. Those with thin sides, especially in the smaller sizes, are likely to slip out of place and leave openings. Some manufacturers who ship tile make them with thin sides to reduce the weight and the consequent cost of transportation. A 4-inch tile should weigh at least 6 pounds, a 5-inch 8 pounds, and a 6-inch 11 pounds. Some factories make them heavier than this, which is better, so far as utility is concerned.

Tile factories are located in those sections where the product is most used. In places where tile are needed and can not be obtained at a reasonable cost, a plan often followed with success is to make them in connection with a brick plant. The additional molding and drying apparatus required can be secured at a small cost, and if covered kilns are used the burning can be done satisfactorily. The open-top kiln may be employed, but ordinarily in this type some of the tile are not well burned. The plan of making tile in connection with a brick factory is recommended for the South, where tile are needed but where the demand is not yet sufficient to warrant the establishment of special factories.

CEMENT TILE.

Cement tile, made of cement and sand or gravel, have been used extensively only within the past few years. Most of these are now made in Iowa and Minnesota, where they are sold in competition with the clay tile. The smaller sizes, that is, under 12 inches in diameter, can not be made as cheaply from cement as from clay, but over that size the cost of production is less. Cement tile properly made have a special place in those sections where the clay tile are not made or where they can not be bought at a reasonable price. The manufacture of good cement tile is a careful process, and unless it is well done the tile are likely to break down when laid. On account of defects in the making there have been many failures with these tile.

There are a number of cement machines on the market with which the careful farmer can make his own supply. These machines are operated either by hand or by steam or gasoline and can be purchased for from \$40 to \$100. Only the best cement should be used. The sand or gravel, or the "aggregate," as it is called, should be free from dirt and if possible should be of various sizes. Bank sand or gravel is better than creek sand or quicksand. Crushed gravel or stone is suitable, but the size of the aggregate should never be more than one-half the thickness of the wall of the tile. To make the best product on the farm 1 part of cement, by measure, should be used to 3 parts of the aggregate. With good sand and careful handling the proportion may be 1 to 4, but this is not generally advisable. The close proportion is necessary to make the tile strong and less porous. Where wider proportions are used the tile are likely to break down

when placed in the ground. The old idea that cement tile should be porous is erroneous. The less porous the tile, whether clay or cement, the better it is for all purposes.

The cement and the aggregate should be well mixed before molding. Too much emphasis can not be placed upon this point. Sufficient water should be added to make the mixture moist. A wet mixture makes a less porous product, and therefore is preferred to a drier one, although it requires more molds to keep the machine going, as the molds can not be removed so soon after making. It is essential that the machine have a packer that will pack the mixture in the molds well; otherwise there will be defects in the tile.

The curing is a crucial point. When the tile are taken from the machine they should be placed in the shade. The longer the mold is allowed to remain around the tile the better. After the mold is removed the tile should be sprinkled twice a day for three or four days or until thoroughly cured. Care must be taken not to miss any in sprinkling, as this will cause checks and cracks. After curing, the tile can be stored in any place desired until used. A well-made and well-cured cement tile, like a good clay tile, when struck with a piece of iron, will have a sharp metallic ring.

Large cement-tile factories in several States are equipped with steam driers, with which the curing can be done to the best advantage. Owing to the failure of many farmers to proceed properly, particularly in curing, some of the larger cement companies advocate the manufacture of such tile only in these factories.

One barrel or 4 cubic feet of cement used in the proportion of 1 to 3 will make approximately the following number of the various sizes of tile:

Size.	Number.
4-inch-----	245
5-inch-----	176
6-inch-----	135
7-inch-----	105
8-inch-----	81
10-inch-----	58
12-inch-----	41

With a hand machine one or two men will make two hundred 4-inch tile per man per day. With power attachment the capacity is greater. Knowing the price of cement and sand and the expense of operating a machine under farm conditions, the cost of tile can be easily ascertained.

PROPER SIZE OF TILE.

No tile smaller than 3 inches in diameter should be laid. The 3-inch tile are recommended only where the laterals are close together and the fall is ample. Even under these conditions their advisability

is questioned. A few 3-inch tile were laid in Illinois when tile drainage was first introduced, but they were soon discarded. The manufacture of this size in that State was discontinued 25 years ago, and in Iowa it was never really begun.

The smallest size now found in common use in these States is the 4-inch, and the tendency in large drainage projects in both Illinois and Iowa is to use nothing smaller than 5-inch tile. It is claimed by the farmers that the 5-inch are more efficient even on small areas than the 4-inch tile, and, costing but little more to buy and no more to lay, one is justified in using the larger size. The use of 4-inch tile, however, should not be wholly abandoned, as they are large enough to be easily laid, and within their limitations do satisfactory service.

It can be seen from these statements that no hard and fast rule for the size of tile can be given. To be of the highest efficiency the tile must be of sufficient size to remove all surplus water before the crops are injured, even after the heaviest rainfall in a continued wet period. It is better to use too large tile than too small. In actual practice with the dark silt-loam soils of Illinois and Iowa, where the rainfall approximates 36 inches a year, an 8-inch tile with a fall of 2 inches to 100 feet will furnish an outlet for the complete drainage of 40 acres, a 7-inch for 30 acres, a 6-inch for 19 acres, a 5-inch for 10 acres, and a 4-inch for 6 acres. On stiff soils with equal rainfall the same-sized outlets will be found adequate, but on the level soils of the South Atlantic and Gulf States, where the rainfall is heavier, only about three-fourths of the area can be drained with the same-sized tile.

Where the lands are rolling, a part of the water is taken off on the surface. Random drainage is here used, and the acreage which the tile will drain is accordingly greater. With a greater fall larger areas can be drained.

LOCATING THE TILE DRAIN.

A system of tile drainage may consist of a main, submains, laterals, and sublaterals. The main is the drain through which all the water eventually flows. A submain collects the water from the laterals and carries it to the main. A lateral is a branch drain that empties into a main or submain, while a sublateral is a branch that empties into a lateral. A system may contain all these parts or it may consist of only a main and a lateral. Sometimes only a single line may be necessary.

The farmer, knowing his land, the supply of labor, and his ability to finance a drainage project, is in a better position to decide when to tile-drain and where to locate the drains than any other person.

Fully 90 per cent of the tile-drainage work in the United States has been done under the farmers' own plans and directions. The plan that is widely followed in the Middle Western States has much to recommend it. Here the farmer decides upon the drainage he wants, locates the drains, and then engages a surveyor or civil engineer to do the leveling.

Where it is possible to install a whole drainage system on a farm at one time it is by all means advisable. In actual practice, however, such a condition seldom occurs. Not many farmers have the money, time, or labor to do it all within a short period, or even within a year. Therefore most of the tile-drainage work must be

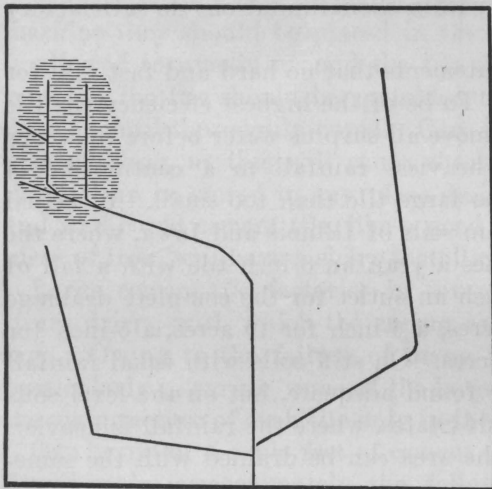


FIG. 3.—Sketch showing a "random" drainage system and the location of tile used in draining 40 acres of land in Scott County, Ill. Only part of this land needed drainage.

done as it has been done in the past, a part at a time, until it is all accomplished. This means that the farmer should first drain those parts of his farm that need it most or on which the profits will be the greatest, locating the drains in the lowest places, or where the surface water flows after a heavy rain. As the work progresses he can observe the results, make improvements in the methods, and decide for himself what further land needs drainage. The ultimate sys-

tem, however, should always be kept well in mind. The mains should be put in first. The system as a whole may be either of two kinds—at random or complete. In the random system (fig. 3) only the wet places, or those which the farmer thinks must be drained, are underlaid with tile. The random system is most commonly used on rolling lands. The complete system is one in which all the land is artificially drained. This is illustrated in figures 4 and 5.

In laying out a system for economy in installing, few mains and long laterals should be used. Near the mains both the laterals and the mains drain the land; consequently, the less overlapping the less the waste by double draining. For this reason the number of tile and the cost of putting them in is greater in the system illustrated in figure 4 than in the one shown in figure 5, although the two systems drain equal areas of land.

DEPTH OF TILE AND DISTANCE BETWEEN LATERALS.

The depth of the tile and the distance between the laterals can not be determined without knowing all the conditions. The deeper the drain the wider the area it will drain, so in open soils it is economy to have the drains deep and far apart. The roots of plants penetrate the soil farther with deep than with shallow drains. Tile, however,

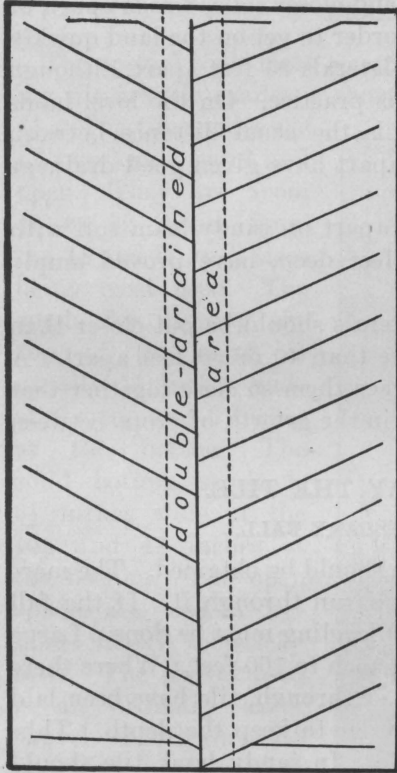


FIG. 4.—Sketch showing a system of drainage in which the cost of installing is increased by too much double draining.

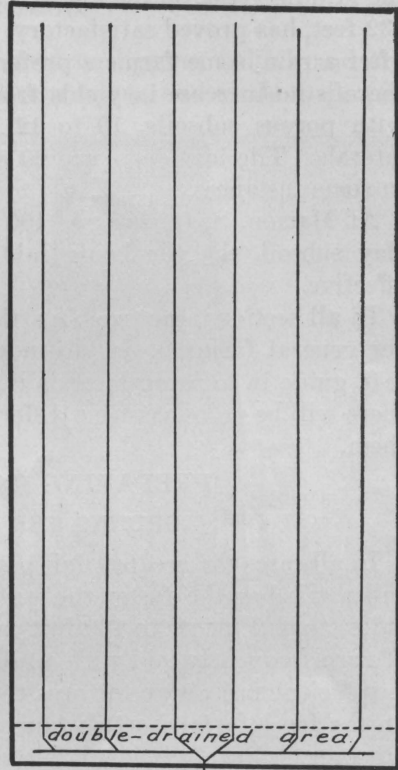


FIG. 5.—Sketch showing a system of drainage by which the area of double-drained land is reduced to a minimum.

should be put sufficiently shallow to allow the water to get down to them and be carried away before it injures a growing crop. In the East, on close, stiff soils, from 2 to 3 feet is considered the best depth, with an increasing tendency to put them deeper. In the Middle Western States, on the black lands with joint-clay subsoil, from 3 to 4 feet, with an average of $3\frac{1}{2}$ feet, has proved the most successful. In the South, on the sandy-loam soils with a clay subsoil, tile $3\frac{1}{2}$ feet deep give satisfactory results. In cutting through high places to get to lower levels it may be necessary to dig deeper than is here suggested, but there may be no drainage of the land where the tile is

deepest. In peat and muck soils the land is likely to settle after it is drained. For this reason, to preserve their alignment the tile should be put down in the clay or they will have to be relaid after a few years.

In the East, for general farming purposes, the laterals are placed from 32 to 70 feet apart. In draining orchards a lateral is often laid between each two rows of trees, regardless of the distance apart. In the Middle West, on the higher lands and closer soils, 8 rods apart, or 132 feet, has proved satisfactory. In order to get on the land quickly after a rain, some farmers prefer the laterals 95 feet apart, although there is no increase in yields from this practice. On the level lands with porous subsoils, 10 to 12 rods is the usual distance between laterals. Tile laid deep and 20 rods apart have given good drainage in some instances.

At Marion, S. C., laterals 100 feet apart on sandy-loam soil with clay subsoil, the tile being laid $3\frac{1}{2}$ feet deep, have proved amply effective.

In all sections, for trucking, the laterals should be put closer than for general farming, usually not more than 40 or 50 feet apart. A safe guide in locating laterals is to place them so close together that there will be no perceptible difference in the growth of crops between them.

PREPARING TO LAY THE TILE.

GETTING THE NECESSARY FALL.

In all cases the greatest fall possible should be obtained. The more fall a tile has the faster the water will run through it. If the fall is less than 2 inches to 100 feet careful leveling must be done. Large tile are frequently laid with a fall of 1 inch to 100 feet. Where there is sufficient fall above to force the water through, tile have been laid on the level for a short distance, in order to keep the depth. This, however, is rarely a good thing to do. In sandy land, tile should have at least 3 inches to 100 feet, so that any sand that enters may be washed out. For tile 4 inches and larger a fall of 3 inches to 100 feet is considered good on any ordinary soil.

If the land is level, the drain must be started deep at the outlet in order to get the fall. Thus, if there is no fall in the surface for 1,000 feet, 2 inches to 100 feet can be obtained by starting the drain 5 feet deep at the outlet and running out to 3 feet 4 inches at the source.

Where the outlet is not low enough there are several methods by which the proper fall for tile can be secured. All of these methods are dependent on pumping. One plan is to run the drain into a well and then pump the water to a higher level, from which it is carried to the outlet. During heavy rains the mouth of a tile drain may be submerged and rendered useless until the water goes down.

Where this condition is likely to prevail for several days, or long enough to injure the system or the crops, a silt basin with two compartments has proved successful. A trap between these compartments is closed in times of high water and the water pumped from the first into the second. As this gives the water a good head, it is forced out. When the water goes down, the trap is opened and the pumping ceases.

DRAINAGE TOOLS.

The special tools most commonly used in digging a ditch and laying tile are tile spades, a shovel, a drain scoop, and a tile hook (fig. 6). The tile spades are of two kinds, solid and open. They are from 16 to 22 inches long, the 18 and 20 inch sizes being most used. The spade for digging the top of the ditch is usually $5\frac{1}{2}$ inches wide at the top and 6 inches at the bottom. The solid bottom spade is $5\frac{1}{2}$ inches wide at the top and $4\frac{1}{2}$ inches at the bottom. The open spades are used in digging mucky or sticky soils. The shovel used is an ordinary earth shovel. The drain scoop is made in various sizes to suit the size of the tile. These are not over 8 inches, however, but can be used for larger tile if necessary. All these tools except



FIG. 6.—Drainage tools. Description (from left to right): Solid top spade, solid bottom spade, dirt shovel, 4-inch drain cleaner, 5-inch drain cleaner, tile hook, open top spade, and open bottom spade.

the tile hook can be bought on the open market; if not from a local dealer, certainly from a wholesale hardware company. The hook can be made by any good blacksmith by taking the handle of an old rake, hoe, or fork and fastening a hook in the end. This hook is made from a $\frac{1}{2}$ -inch rod, and is 9 to 10 inches long.

Several machines are made for digging the ditches for tile drains. The best known of these is the trenching machine. This has proved

profitable enough where there is sufficient drainage work either on an individual farm or in a community to warrant the purchase of a machine. An efficient operator, long laterals, and short distances between jobs make its use more advantageous. On ordinary soils the traction ditcher will dig the ditch cheaper than hand labor, but it is not well adapted for stony or stumpy land.

DIGGING THE DITCH.

A ditch should be started at the outlet and dug by a line. It must be kept clean-cut and straight, for any crook that occurs in the top is likely to be greater in the bottom. If the direction is changed it should be done by an easy curve. In following an old watercourse the tile should take a straight route and not follow the bed of the stream (fig. 7). Sharp turns must be avoided. Where a lateral joins a main or submain it should be at a small angle, so that when

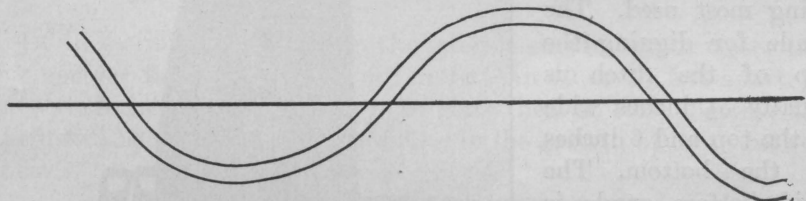


FIG. 7.—Sketch showing the straight course that a tile drain should take instead of following the sharp turns of an old watercourse.

the tile are laid the velocity of the water flowing from one into the other will be but little checked.

The ditch need be no wider than is necessary for the laborers to work in conveniently, as an extra width means unnecessary removal of earth. For a 4-foot drain with a 6-inch tile, or smaller, 12 inches at the top is ample. For deeper drains or larger tile more space is required. A ditch not more than 34 inches deep can be made in two spadings with 18-inch spades, but for ditches deeper than that the surface must be removed with a shovel or an extra spading taken.

Figure 8 shows a 41-inch ditch for tile. It is 12 inches wide at the top and 7 inches at the bottom. The first man removed 9 inches of earth with a shovel. The second man, using an 18-inch spade, threw out 16 inches and then cleaned out his crumbs with a shovel. Both of these men were careful to keep the bottom of their digging uniform; that is, there were no dips in it. The third man used an 18-inch bottom spade (see fig. 6) and, by having a level place from which to dig, dug within an inch of the bottom. After he had worked back 4 or 5 feet he laid aside his spade, took up the tile scoop, removed the crumbs, and finished the drain to the proper

grade. Care was taken to make the bottom round and smooth, and when this man left it the drain was ready for the tile. At no time did the last man stand in the bottom, nor is it good practice for anyone to do so while making a ditch unless it is for large tile and the bottom is wide and firm. The method employed in making this ditch is the one commonly used on ordinary soils by all good ditchers.

Where stones are encountered, picks and shovels may be found best for making ditches. All stones and stumps should be removed and

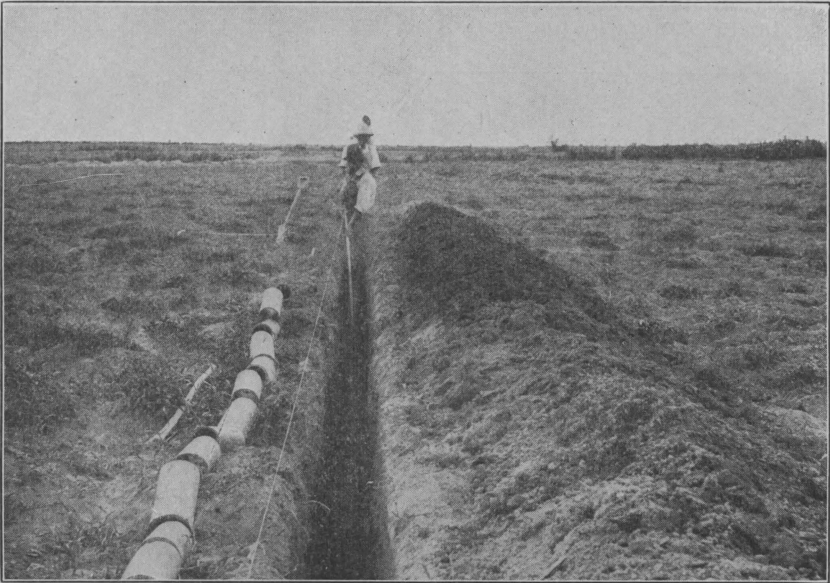


FIG. 8.—Laborers digging a ditch preparatory to laying tile at Columbia, S. C.

not avoided by running the ditch around them. A proper quantity of moisture in the ground facilitates the work, as it is difficult to do the digging and make a good bottom either when there is too much water or when the soil is dry and hard.

DIGGING TO THE GRADE.

Digging to the grade and making the bottom are the crucial operations in excavating for a drain.

Where there is plenty of fall the grade is often made in wet seasons or on wet lands by using the water for a level. If the water runs from the ditcher as the bottom is made, it indicates that there is sufficient fall. Where there is no water, a ditcher's level or a straight edge and carpenter's level may be of service.

If the fall is less than 2 inches to 100 feet or if it is necessary to go through a rise in the ground to get to a low place beyond, for the best work an engineer should run the levels and set stakes 50 feet

apart to indicate the grade. Several methods are in use by which the bottom can be graded from these stakes. If the workmen are not familiar with one of these, then the engineer should instruct them, as he can demonstrate the method better than it can be described. In all cases the bottom should be accurately leveled so that no water will stand in the ditch.

One plan often used is to stretch a tight line on crossbars directly over the ditch and 7 feet above the proposed bottom (fig. 9). By measuring from this line with a 7-foot pole the location of the bottom is determined. The height of the line is measured from the

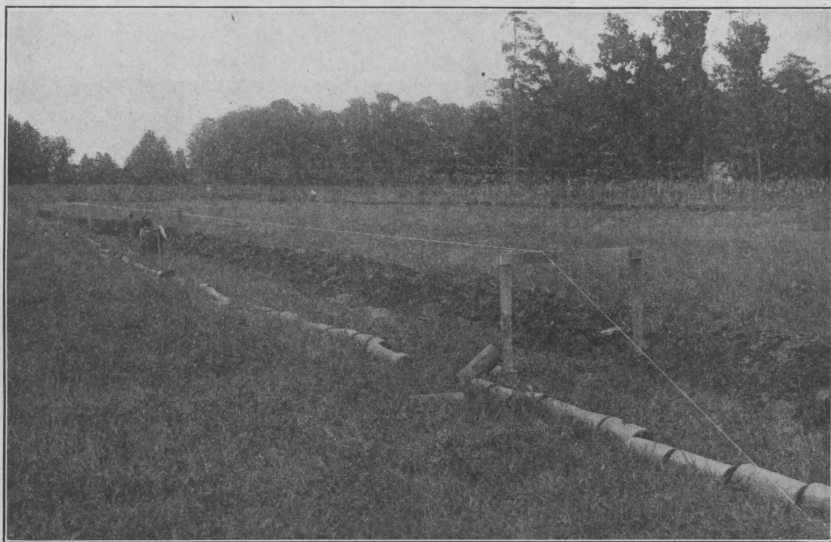


FIG. 9.—Laborer digging to the grade by means of crossbars and a tight line.

grade stakes. The engineer calculates the depth of the cut, and the line is placed high enough to make the cut and the distance of the line above the stakes equal the length of the measuring pole. Thus, if the cut is 3 feet 8 inches, the line must be 3 feet 4 inches above the grade stake to be 7 feet above the proposed bottom. The crossbars are set at each grade stake, or 50 feet apart. In measuring the height the first stake or the hub is driven down so that the crossbar is the required distance above the grade stake. Then the other stake is driven down on the opposite side of the ditch until a carpenter's level shows that the crossbar is level. When two or more crossbars are set, the line is drawn tightly from one to the other, held from slipping sideways by a nail, and fastened to stakes driven in the ground at the side of the ditch. A $5\frac{1}{2}$ or a 6 foot measuring pole, instead of one 7 feet long, may be used, but the height of the line above the grade stakes must be decreased accordingly.

LAYING THE TILE.

Laying the tile, like digging the ditch, should begin at the outlet. Under ordinary conditions tile should be laid every day as far as the



FIG. 10.—Laborer laying tile.

ditch is made. Any delay in laying may cause injury to the ditch by rain or by particles falling into it. If the banks are likely to cave, the tile should be laid as fast as the ditch is completed.

The smaller sizes are laid from the bank with a hook, as shown in figure 10. Large sizes must be laid by hand from the bottom of the ditch. All misshaped and cracked tile should be discarded. If a tile does not join closely with the preceding one it should be turned over until it fits at the top. Any large cracks are covered with pieces of tile. Where a lateral joins to a main or a submain the connection should be made with a Y (fig. 11). Neither a T nor an elbow is desirable, as these check the flow of water.

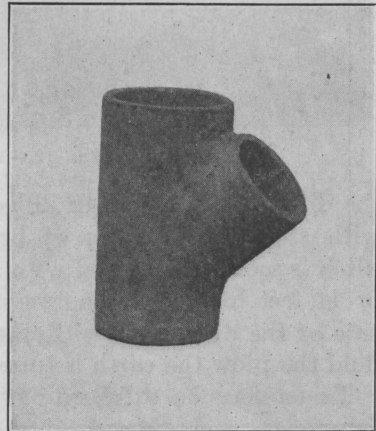


FIG. 11.—A 4 by 6 inch Y tile.

When the tile are laid and inspected they are ready for priming. This is done by caving a little earth from the sides of the ditch (fig. 12) and letting it settle gently, so as to keep from knocking the tile out of line.

In sandy soils there may be danger of the sand entering the tiles and clogging the drain. This can be prevented by covering the joints with pieces of old sacks or straw.

FILLING THE DITCH.

After the tile are primed they may remain without injury for several days or until all the ditches are ready for filling. If the soil is close and it is desirable to aid the water in reaching the tile quickly,



FIG. 12.—Laborer priming tile.

the ditch can be partially filled with straw or brush, or, better still, with stones and pieces of brick. Under ordinary conditions the ditch is most easily filled with a turnplow and an evener, which is 12 or 14 feet long. Two horses are hitched to this plow, one on each side of the ditch, and with one man to lead or drive and another to hold the plow the earth is turned in. (See fig. 13.)

There may be extraordinary conditions, however, where a plow can not be used. By placing the team on one side of the ditch and a wooden scraper on the other side in such cases the dirt can be pulled in rapidly. Filling by hand is usually the most difficult and most expensive method.

HOW WATER ENTERS THE TILE.

When a rain falls the water enters the soil, passes through the pores until it reaches the drain, and then enters the tile through the cracks at the joints. The quantity that enters through the sides of even the most porous tile is not worth considering. With the most careful laying there is always ample room for the water to pass through at the joints. The longer the tile are laid, the more open the pores in the soil become and the better is the drainage. Thus, a



FIG. 13.—Laborers filling a ditch with a turnplow to which a long evener is attached.

system of tiling which appears unsatisfactory at first may prove adequate in the course of time. Naturally the more porous the soil the more readily water will pass through it. The percolation in close soils is improved by deep plowing and subsoiling.

LIFE OF A TILE DRAIN.

The life of a tile is unknown. The first in the United States were laid in New York nearly 75 years ago and these are now doing as good service as ever. There are numerous instances where tile have been in use more than 50 years with no sign of deterioration. In fact, a drain of good tile properly laid may be considered permanent.

USE OF SILT BASINS OR SAND TRAPS.

Silt basins or sand traps are used to catch silt, sand, or any other material that gets into the tile and to furnish a connection between laterals and mains or submains. They also serve as intakes for surface water and as a place to inspect the tile. Such a basin extends 2 or 3 feet below the tile. It is walled up with brick or some other material and is covered. Two or three large sewer pipes standing on end with openings in the sides make a good basin.

PROTECTION OF THE MOUTH OF A DRAIN.

The bank at the mouth of a drain should be kept from caving and closing it. This can be done with a cement wall, as shown in figure



FIG. 14.—Mouth of a tile drain.

14. Stone and brick will answer the same purpose. Sometimes several feet of pipe made of corrugated galvanized iron or other metal are used. Any injury to the mouth of the tile whereby the water is held is ruinous to the whole system. Wires placed over the end will keep animals from entering. A valve may be used to keep the water from backing into the drain when the mouth is submerged.

LANDS THAT REQUIRE ARTIFICIAL DRAINAGE.

Lands that are too wet for the most profitable production of crops can usually be easily pointed out. These include wet level land, low

spots, flat areas underlain with clay on the summits of knolls and in swamps, river and creek bottoms, and peat bogs.

Lands that may or may not be too wet for cultivation but which are improved by drainage are hillsides subject to erosion, stiff soils, and sour or alkaline spots.

Open, sandy soils with a rolling surface need no artificial drainage except in occasional depressions where the water accumulates. Some porous soils with good surface drainage may be improved by artificial drainage, but often not enough to pay for the cost.

In sections like northern Minnesota and eastern North Dakota, where the annual rainfall, although light, is not uniformly distributed, but comes in a few spring and summer months, artificial drainage is essential to the most profitable production of crops.

DRAINING HILLSIDES.

Underground drainage is frequently found profitable on hills and hillsides in impeding erosion, draining seepy places, and improving the productiveness of the soil. Thus, on the so-called abandoned hill farms of New York, underdrainage is one of the first requisites in making the soils productive. On the gently sloping lands in the South a part or all of the terraces may be removed by underdrainage, while on steeper lands the number may be decreased.

In draining hillsides the tile may be run diagonally around the slope or, as is recommended in most cases, straight or nearly straight up the side. A diagonal drain will not take water from the lower side; hence, it will not drain so great an area as the vertical method. Where there are natural draws down the hillside the tile should follow these. Under all circumstances the drains should be located to catch the most water.

Where water runs off the hillsides and floods a level or swampy area below, the low lands can be protected by placing an open ditch or a tile drain around the base of the hill. If an open ditch is made, the earth should be thrown on the lower side for a levee. Whatever drain is employed, in order to intercept all the seepage water it must be deep.

DRAINING PONDS.

In draining ponds or potholes where the water from the surrounding lands collects, the tile must be larger and laid closer together than on level land, as in reality there is more area than the pond to drain. A line of tile run around the edge will intercept any seepage water (fig. 15). Where the top soil in a pond is mucky and will not let the water through, an intake will do much to relieve the situation. In order to reach a pond or low place, the outlet tile

must often be placed deep to secure a proper fall. There is no objection to this, but it may be too deep to drain the land it passes through.

COST OF TILE DRAINAGE.

Drainage outlets constructed for a farm or a district cost various sums per acre of land, depending upon the nature of the outlet and of the area in the district benefited. The price for excavating a large ditch varies from 8 to 14 cents a cubic yard. This may make the cost per acre as low as \$1 or in exceptional cases \$15 or more. Not many outlets, however, cost over \$4 for every acre of land drained. Of

course, if an adequate outlet is already present, this part of the expense is eliminated.

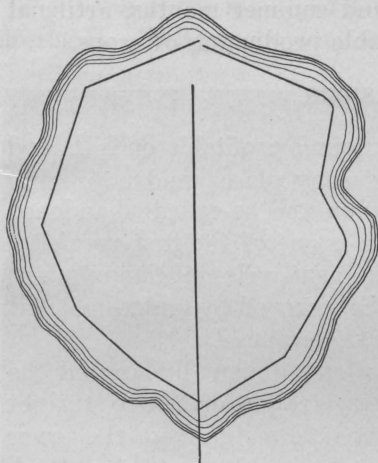


FIG. 15.—Sketch showing a line of tile laid around the edge of a pond to intercept seepage water and across the pond to drain it.

The cost of tile drainage is influenced by the price of tile, the transportation expenses from the factory to the farm, the cost of digging the ditch, laying and priming the tile, and filling the ditch. The price of tile varies with the section in which it is manufactured. In Ohio, Indiana, Illinois, and Iowa, where most of it is made and the competition is strongest, the price is the lowest. In the East, where the manufacturers sell just low enough to compete with the delivered price of the Middle West,

the cost is higher. Southern prices are practically the same as in the East, while in the far West tile are higher than in any other part of the country. Most factories sell tile by the thousand feet. In the Middle West the following prices of the various sizes prevail:

Size.	Price per 1,000 feet.
4-inch-----	\$13 to \$16
5-inch-----	18 to 23
6-inch-----	24 to 34
7-inch-----	34 to 48
8-inch-----	48 to 60
10-inch-----	60 to 110
12-inch-----	90 to 150

Prices in the East and South are about 50 per cent in excess of these, while in the far West they are about 70 per cent higher.

The expense of transportation is determined by the distance tile are shipped and the cost of hauling them from the station to the farm.

Digging the ditch and laying and priming the tile are usually figured as one operation. This is done either at so much per rod or by the day, the former being the more common practice. The price of the work and the amount accomplished per day are affected by the size and depth of the tile, the character of the soil, and the skill of the workmen. The work is cheapest in the Middle West, while higher rates prevail in the East and South. A skilled workman, one who digs rapidly and is capable of making the bottom, generally earns from \$2 to \$3.50 a day. Unskilled laborers may be secured for \$1 to \$1.50 a day. On ordinary soils in the Middle West the average capacity of a good workman with a 3-foot ditch and not over 5-inch tile is 10 rods a day. In the East and South sometimes, on account of the character of the soil, the capacity of a man is from 4 to 8 rods with the same depth and the same size of tile. An average price in the Middle West for a 3-foot ditch is from 25 to 30 cents per rod with 4 or 5 inch tile, 35 to 40 cents for 6-inch, and 50 cents for 8-inch. For ditches deeper than 3 feet, the price usually increases at the rate of 1 cent per rod for every additional inch in depth. Ordinarily, however, the price is figured on the average depth of the entire ditch. The ditch can be filled with a plow for 3 cents per rod, and sometimes for 2 cents. When done by hand or with a scraper it is much more than this.

The cost of drainage per acre will, in addition to these factors, depend on the tile required. If laterals are laid 100 feet apart it will take 436 tile for every acre, in addition to the tile needed for the main and submains. If 4-inch tile at \$20 per thousand, including transportation, are used, the tile would cost \$8.72. The cost of digging the ditch and laying and priming the tile, at 30 cents per rod, would be \$7.93, and the filling, at 3 cents per rod, 79 cents. Thus, the cost per acre, exclusive of the mains, submains, and outlets, totals \$17.44. With closer laterals, or larger tile, of course the cost will be greater. However, where land does not require thorough drainage the maximum benefits may be obtained with an expenditure of \$7 or \$8 per acre. The cost of drainage is therefore a problem in itself and must be determined for the locality in which it is done.

BENEFITS OF DRAINAGE.

The benefits of drainage are readily apparent to any intelligent observer. Some of the most obvious results are as follows:

It usually increases the yields and profits of crops.

It makes lands that are uncertain in production produce crops every year.

It brings into cultivation lands otherwise worthless. Not only can swamp lands be made tillable, but on farms where there are places too wet to cultivate, drainage will improve the land and cause it to produce good crops.

Drainage improves the physical condition of the soil by making it more granulated, porous, and friable. Thus, stiff soils are more easily handled, the plants have a greater feeding area, and the available moisture in the soil is increased. Soils also absorb more of a rainfall, thereby decreasing erosion and damage by floods.

Drainage warms the soil. The evaporation of moisture by the sun requires heat which, if the excessive moisture is removed by drainage, is used in warming the soil. This is noticeable in the North, where the planting season is from one to two weeks earlier on drained than on undrained land. The danger of damage by frost both in the spring and in the fall is reduced.

The warming of the soil by drainage causes the seed to germinate more readily, thereby giving a better stand of crops and causing the plants to grow more promptly.

Drainage aids in the preparation of land and the tillage of crops. Land can be plowed earlier in the spring and is better pulverized. Crops can be cultivated sooner after a rain, and by closing small ditches with tile drains more improved machinery can be used and the cost of cultivation decreased.

Drainage improves the health conditions. Perhaps there is no better illustration of this than the number of mosquitos that were found in parts of Illinois and Iowa when first settled. When the land was drained most of the breeding places of the mosquitos were removed and with them the consequent malaria.

PROFITS FROM DRAINING.

It is not uncommon for lands too wet for cultivation to produce when drained 60 to 70 bushels of corn and oats or from 1 bale to 1½ bales of cotton per acre. On a great deal of land the increase in yields is often from 25 to 100 per cent. In some years on some wet soils drainage may not pay, while on others it may be necessary in order to save the entire crop. By increasing the yields and decreasing the cost of cultivation, the profits and the value of the land are often doubled.

The writer has met thousands of farmers who have used tile drainage, but in no instance where the work was properly done has he found anyone dissatisfied. Farmers in the East who have used tile drainage state that it is one of the most profitable investments made on the farm. A planter in South Carolina with three years' experience stated that tile drainage had made land that never produced

a crop before grow heavy crops of cotton, corn, oats, and cowpeas, and on other land had increased the yields and decreased the cost of production.

Perhaps the situation is best summed up, however, in the following statement of a farmer with 32 years' experience in Illinois who owned 1,000 acres of land, all of which he had drained: "On soils needing drainage, no farmer can afford to be without it."



